AD 424616

STEVENS INSTITUTE OF TECHNOLOGY

CASTLE POINT STATION
HOBOKEN, NEW JERSEY

DAVIDSON LABORATORY

DAVIDSON LABORATORY
REPORT 966

June 1963

EXPERIMENTAL MEASUREMENTS OF THE DEFORMATION OF REGULAR HEAD AND FOLLOWING SEAS BY A SHIP MODEL

by

Paul G. Spens

The Research was carried out under
Bureau of Ships Fundamental Hydromechanics Research Program
S-R009-01-01
Contract Nonr 263(54)
Administered by the David Taylor Model Basin
(DL Project 2698/058)

Approved

Edward Numata

Edward Numata, Chief
Ship Research Division

ABSTRACT

This report describes measurements of the changes in amplitude of regular head and following waves as they passed along the length of a ship model for model speeds zero, Froude number 0.1, and Froude number 0.3.

In head seas the height of the incident wave diminished by some 20% to 40% as it passed along the length of the fully restrained model from bow to stern. In following seas the wave diminished by some 50%, from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas, there are local variations of wave height near the bow which are not predicted by the theory.

TABLE OF CONTENTS

INTRODUCTION

Thanks to recent work of Grim, Tasai, Porter, and others, considerable progress has been made in the theoretical calculation of hydrodynamic forces on two-dimensional forms which are exposed to waves or are oscillating in calm water. Moreover, experimental confirmation of some of these results has been obtained.

The problem presented by a ship in longitudinal waves involves two additional complications: the effects of the three-dimensional form and the effects of the forward speed of the ship. In 1960 Grim published a paper[1] showing how the three-dimensional effect might be calculated for a ship at zero speed. In a more recent paper[2] he has discussed the physical behavior of the wave system which underlies this mathematical treatment, and has taken the first step toward extending the work to the case of a ship with forward speed.

The essential feature of this latter paper is a discussion of the way in which the height of the incident wave is diminished during its passage along the ship. Numerical results are given, both for the stationary ship and for the ship with forward speeds. The experiments in head and following seas, described in the present report, were intended to verify this calculated variation of the wave height as the wave travels along the ship.

This study was sponsored by the Bureau of Ships Fundamental Hydromechanics Research Program and technically administered by the David Taylor Model Basin under Contract Nonr 263 (54), Research Program S-R009-01-01 (DL Project 2698/058).

APPARATUS AND TEST PROCEDURE

Model

A wooden model (DL Model 2698) was constructed of the form given in Grim's 1960 paper,[1] for which form theoretical results are available. The form was defined by Grim as follows:-

Length/Max Beam = 6.4 Max Beam/Draft = 2.8

Section Coefficient = 0.9 (Same for all sections)

Station	1	3	5	7	9	11	13	15	17	19
Section Beam/Max Beam	.33	.7	.9	.99	1.0	1.0	.99	.9	.7	.33

Offsets were computed on the IBM 1620 for the appropriate Lewis form sections, and the body plan is shown in Fig. 1. The model had the following dimensions:-

Length	60 in.
Beam	9.38 in.
Draft	3.35 in.
Freeboard	4.0 in.

The sides were vertical above the water line.

Test Arrangement

A photograph of the test setup appears as Fig. 2.

The tests were carried out in Davidson Laboratory Tank No. 2, which is 75 ft square. The movable bridge carrying the rail and carriage was set up with the direction of motion of the carriage parallel to that of the waves. Thus tests in head and following seas could be undertaken. As the model was 20 ft from the nearest side-wall of the tank, effects due to reflection of waves generated by the model from the side of the tank were minimized.

The model was rigidly attached to the carriage by a strut. The carriage also carried a number of wave probes, disposed in a line parallel to the fore-and-aft axis of the model. One wave probe was located amidships, 1 in. (later increased to 2 in.) from the side of the model. Other wave probes were abreast the quarter points, abreast the bow and stern, 2 ft ahead of the bow, and, in some runs, 2 ft abaft the stern. The heights indicated by the several wave probes were recorded simultaneously on a multichannel Sanborn recording system.

Wave Measurement

The fore-and-aft locations of the wave probes are shown in the plan in Fig. 4. Some changes of position were made in the course of the trial, to minimize interference of the ship-wave system with measurement of the incident waves.

The requirement for wave measurement at several points near the model raised certain problems. In the first place, the wave probes of the resistance type normally used at this laboratory interfere with each other's readings when less than some 2 ft apart. A special wave probe was therefore designed, in which two vertical stainless-steel wires .01 in. in diameter penetrating the water surface are supported 1/2 in. apart. The electrical resistance of the water between these wires was measured by an A.C. bridge system. This arrangement gave deflections of the Sanborn recording galvanometers linearly proportional to wave height, and the probes showed no interaction when only 6 in. apart. The wave probes can be seen in Fig. 2, and details of the bridge circuit are given in Fig. 3.

Another problem arising from the use of several wave probes was that the supports for the wave probes might make a wake which would lead to incorrect measurement of the

waves by wave probes farther aft. For this reason the wave-probe supports were made as small as possible, and, in fact, each consisted of two curved stainless-steel wires .06 in. in diameter, which may be seen in Fig. 2.

Since it was essential in this project that the wave-probe calibrations be reliable, special calibrating arrangements were provided. All the wave probes were mounted on an aluminum T-bar, which was suspended from the main carriage in such a way that it could be raised and lowered by the rotation of screwed rods near each end. These rods were rotated by a reversible D.C. motor, through a horizontal shaft and bevel gears. A Selsyn driven from the shaft drove another Selsyn ashore, the latter coupled to a counter which indicated the vertical movement of the wave probes to better than .01 in. This calibrating system proved extremely convenient and the wave-probe calibrations were usually taken between each run and the next.

In practice, the calibrations were found to be quite stable and showed no tendency to drift once the electronic system had thoroughly warmed up. Repeat calibrations showed a scatter of about ± 2%, which corresponded to about ± 1/2 mm on the record and could be largely due to reading errors.

A recent investigation at Massachusetts Institute of Technology has shown that wave probes of the type used in the present work can be expected not to introduce errors greater than 1% to 2% in the measurement of the waves which affect them. However, it appears from the scatter of results observed in some of the present experiments that the wave height at a given locality may vary by as much as 10% between one run and another in nominally similar conditions. In general, the trend of the present results is believed to be correct within a few percent, except in cases where much scatter is shown.

Test Conditions

The series of tests covered the following conditions:

Wave Length/Ship Length	.75, 1.0, 1.5, 2.0
Wave Height/Ship Length	1/40
Speeds	Zero F = 0.1 and F = 0.3 in Head and Following Seas

RESULTS

The test results are shown in Figs. 5-10. An explanation of these figures is given below the presentation of Fig. 4a.

In all cases the ordinate plotted represents the observed wave double amplitude divided by the height of the undisturbed incident wave. Since the wave probes moved with the model, the wave system due to the speed of the model caused a constant displacement of the wave record, which was disregarded.

It was found that at zero speed, and in head seas at F = 0.1 (1.23 ft/sec), the wave height at the wave probe 2 ft ahead of the model sometimes showed considerable differences from the nominal wave height. Thus it was apparent that at these speeds the wave height at this point was influenced by the model. Therefore, the wave height observed ahead of the model at the highest speed, F = 0.3 (3.85 ft/sec), was taken as the height of the undisturbed wave for all runs at a given wave-maker setting.

In following seas at both speeds (F = 0.1 and F = 0.3) all the wave probes were more or less affected by

the presence of the model, and runs at $F = 0.3$ at the same wave-maker setting but in the head-sea direction were used to determine the undisturbed wave height.

For comparison with the experimental results, theoretical curves calculated by the methods given by Grim are plotted in those cases for which the necessary computations have been performed. Two theoretical curves are shown, when the computed values are available.

The curve marked H_3 represents the three-dimensional effect; that is, the deformation of the incoming wave in a longitudinal direction. Grim denotes H_3 as the effective wave; it shows the effect of adjacent sections of the ship on the wave height at a given section.

In addition to this longitudinal deformation, a deformation in a transverse direction also takes place, since the wave height at a given section is influenced by the presence of that section of the ship. To a first approximation, this effect is the same as in a two-dimensional case. It is taken into account in ship-motion computations using a strip theory such as that of Korvin-Kroukovsky.[3]

The two effects, longitudinal and transverse deformations, are combined in the curves marked H_{23}, and it is these curves which are directly comparable with the experimental results, since the latter also include both longitudinal and transverse deformations.

The curves H_3 and H_{23} (plotted in Figs. 5-10) have been derived from various sources:

For zero speed, H_3 is taken from Ref. 1. The transverse deformation H_2 was calculated by the two-dimensional theory outlined by Grim in Ref. 1. H_{23} is the product of H_2 and H_3.

For the head-sea cases, H_3 was computed using a program written by Dr. Grim. The transverse deformation was again computed by Grim's two-dimensional theory and was combined with H_3, with due regard for phases.

For the following-sea cases, H_3 was obtained from Ref. 2. Unfortunately, it has not been possible to compute the combined effect H_{23} for these cases.

It may be noted that in Ref. 2 Grim describes the results there given as a first rough quantitative approximation. It is understood that Dr. Grim is at present working on another and, it is hoped, better approximation for the three-dimensional body.

DISCUSSION OF RESULTS

At zero speed the height of the wave decreased fairly steadily as it passed along the ship, and the measured wave deformation was generally in good agreement with the theoretical values given by Grim. There appeared to be a tendency for the wave heights near the stern of the model to be somewhat greater than predicted. This is hardly more than could be accounted for by experimental scatter, except for $\lambda/L = .75$.

For the cases where the model is moving, theoretical results are, unfortunately, available only for $\lambda/L = 1$.

In head seas, at the lower speed $F = 0.1$, the decrease of wave height over the middle half of the model length is in good agreement with theory. Near the bow there is a considerable increase of wave height above the level of the incident wave, which is not predicted by theory. This is further discussed below.

At the higher speed F = 0.3, theory indicates an increase of wave height over almost the whole length of the ship. The form of the theoretical curve is not in agreement with experiment, which showed a considerably increased wave height near the bow, falling abruptly to rather less than the height of the incident wave at and abaft amidships.

At both speeds, rapid variations of height appeared to occur as the wave passed the forward part of the ship. At the higher speed a crest of broken water was thrown off from the bow and moved fore and aft with the period of the incident wave. When it reached the wave probe at the same time as the crest of the incident wave, it seemed from visual observation that the wave height might be considerably overestimated. The wave probe originally at station 1 was therefore moved forward 3 in. to abreast the stem.

The presence of broken water at the wave probe was indicated by noise on the record, and subsequent examination showed that before moving the wave probe there was broken water at the wave probe at both crest and trough for F = 0.3, $\lambda/L = 2$. Moving the probe forward and out of the broken water increased the apparent wave height by some 20%. Later the line of wave probes was moved 1 in. farther from the center line of the model. The combined forward and lateral movement of the wave probe at the bow led to a 20% reduction in apparent wave height for F = 0.1, $\lambda/L = 1$, and a 10% reduction for F = 0.3, $\lambda/L = 1$.

Thus it appeared that abreast the bow there may be abrupt changes in the apparent wave height, since changes of 10% to 20% were observed consequent upon moving the wave probe 3 in. Such changes could be due to model-generated waves of short wavelength oscillating fore and aft with the period of the incident wave. (The photograph in Fig. 2b shows various irregularities of the wave system.) Further,

it is possible that nonlinear interaction between the ship wave and incident wave may account for variations in the apparent amplitude of the latter.

At F = 0.1, a maximum value of wave amplitude was observed abreast the bow, except for $\lambda/L = 3/4$, when there was a minimum abreast the bow and a maximum at 1/4 L abaft the bow. At F = 0.3, all wavelengths showed a maximum wave amplitude 1/4 L abaft the bow. However, in the light of the large effects resulting from small movements of the bow wave-probe, there is some question whether the values measured within 1/4 L abaft the bow might not have been changed very considerably by small movements of the wave probes. The values measured in this region must be viewed with some suspicion. To clarify this question, it would be desirable to perform further experiments, with different wave-probe locations. It would also be most desirable to take movies, in order to obtain a visual impression of the behavior of the waves.

A factor which may influence the behavior of the waves near the bow is that the model used for these tests was designed with mathematical calculations of wave deformation in view, and with little consideration of resistance or wave-making. The half-angle of entrance was 33 deg and the bow wave was larger than would be generated by a finer form. Another consideration is that a real ship is free to move with the waves, whereas the present tests were made with a restrained model. Thus the changes of wave height near the bow may well be less under realistic ship conditions than in the present tests. However, until the matter has been further investigated, it seems desirable to bear in mind the possibility that considerable changes of wave height may occur near the bow of a ship moving into a head sea. Such changes might seriously affect the accuracy of a ship-borne

wave recorder located at the bow, and the effect on a Tucker wave recorder may also be significant.

In following seas, at the lower speed $F = 0.1$, the ship was traveling less rapidly than the group velocity of the waves. The wave height then diminished fairly smoothly as the wave passed along the ship from stern to bow, until, for $\lambda/L = 1$, the wave amplitude at the bow was some 50% of that of the incident wave. The theory predicted 40%.

At the higher speed $F = 0.3$, when the ship speed exceeded the wave group velocity, the wave amplitude diminished from the bow, until, at the stern for $\lambda/L = 1$, it was some 40% of that of the incident wave, compared with the theoretical prediction of 25%.

Thus the experiment confirms the theoretical result that in following seas the trend of wave height along the ship reverses according as the ship speed is greater or less than the wave group velocity.

It is appropriate to discuss, albeit only tentatively, the implication of the predicted and observed wave deformation on the calculation of exciting forces and moments on a ship in waves. In the first place, it should be noted that the wave deformation which has to be considered in this connection is the three-dimensional part, H_3, only. The two-dimensional part, which is also included in the experimental results, appears in the two-dimensional calculation of exciting forces by the usual strip method and so is allowed for in such calculations. Considering the zero speed case, for which there is good agreement between Grim's theory and the present experiments, it seems reasonable to suppose that the reduction of height as the wave moves aft will lead to a reduction in the heaving force, and probably also in the pitching moment. It would certainly be desirable to extend the three-dimensional computations to arrive at the effect

of the wave deformation on the exciting forces. However, it may be remarked that there is reasonable agreement between experimental results for exciting forces and values calculated by two-dimensional strip theory. It seems not unlikely that introduction of the three-dimensional effect may upset this agreement and call for further work on the theory. On the basis of Grim's theory and the present experimental results, one would expect the three-dimensional effects to reduce the exciting forces in following seas even more than those at zero speed. However, the force measurements made by Gersten[4] for a model very similar to that used in the present tests, do not show any large general reduction of heaving force in following seas.

Although the two-dimensional strip theory yields good results in many cases, a more complete hydrodynamic solution is required for a better understanding of such matters as the influence of changes in ship form (especially of section shape) on motion, the added resistance in waves, and the tendency to slamming or wet decks.

CONCLUSIONS

In head seas, the height of the incident wave diminished by some 20% to 40% as it passed along the length of a fully restrained model from bow to stern. In following seas, the wave height diminished by some 50% from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas there are local variations of wave height near the bow which are not predicted by the theory.

RECOMMENDATIONS

Further experiments should be made to examine in more detail the behavior of the wave near the bow, both for the present model and for a finer model similar to, say, the Mariner or Series 60 (0.60 block). In addition to wave measurements, movies should be taken to show the behavior of the wave (see Discussion of Results, p. 9).

Measurements of forces exerted by waves on a ship model should be compared with predictions based on Grim's three-dimensional theory. Measurement of pressures at a few locations on the bottom of the model would be valuable in this connection (see Discussion of Results, p. 11).

Measurements and computations should also be made of the wave deformation caused by a model free to pitch and heave. Pressure measurements on the free model would be valuable, especially at the location of a Tucker ship-borne wave recorder.

Consideration should be given to the possibility that, if large wave deformations exist near the bow of an actual ship, they may bedevil the operation of any ship-borne wave recorder utilizing a sensor at the bow (see Discussion of Results on p. 9).

REFERENCES

1. O. Grim: "Computation of Heaving and Pitching Motions in Smooth Water and in Waves," Third Symposium on Naval Hydrodynamics, Scheveningen, 1960.

2. O. Grim: "Deformation of Regular Head and Following Waves by a Moving Ship," Fourth Symposium on Naval Hydrodynamics, Hamburg, 1962. DL Technical Translation No. 1.

3. B. V. Korvin-Kroukovsky: "Pitching and Heaving Motions of a Ship in Regular Waves," SNAME 1957.

4. A. Gersten: "Comparison of Experimental and Theoretical Forces and Moments on a Restrained Surface Ship in Regular Waves," J. of Ship Res., 1963.

ACKNOWLEDGMENTS

The author wishes to express his appreciation of much helpful advice given by Dr. O. Grim, especially in connection with the theoretical calculations.

Computations were carried out on the IBM 1620 at the Computer Center of Stevens Institute of Technology, which is partly supported by the National Science Foundation.

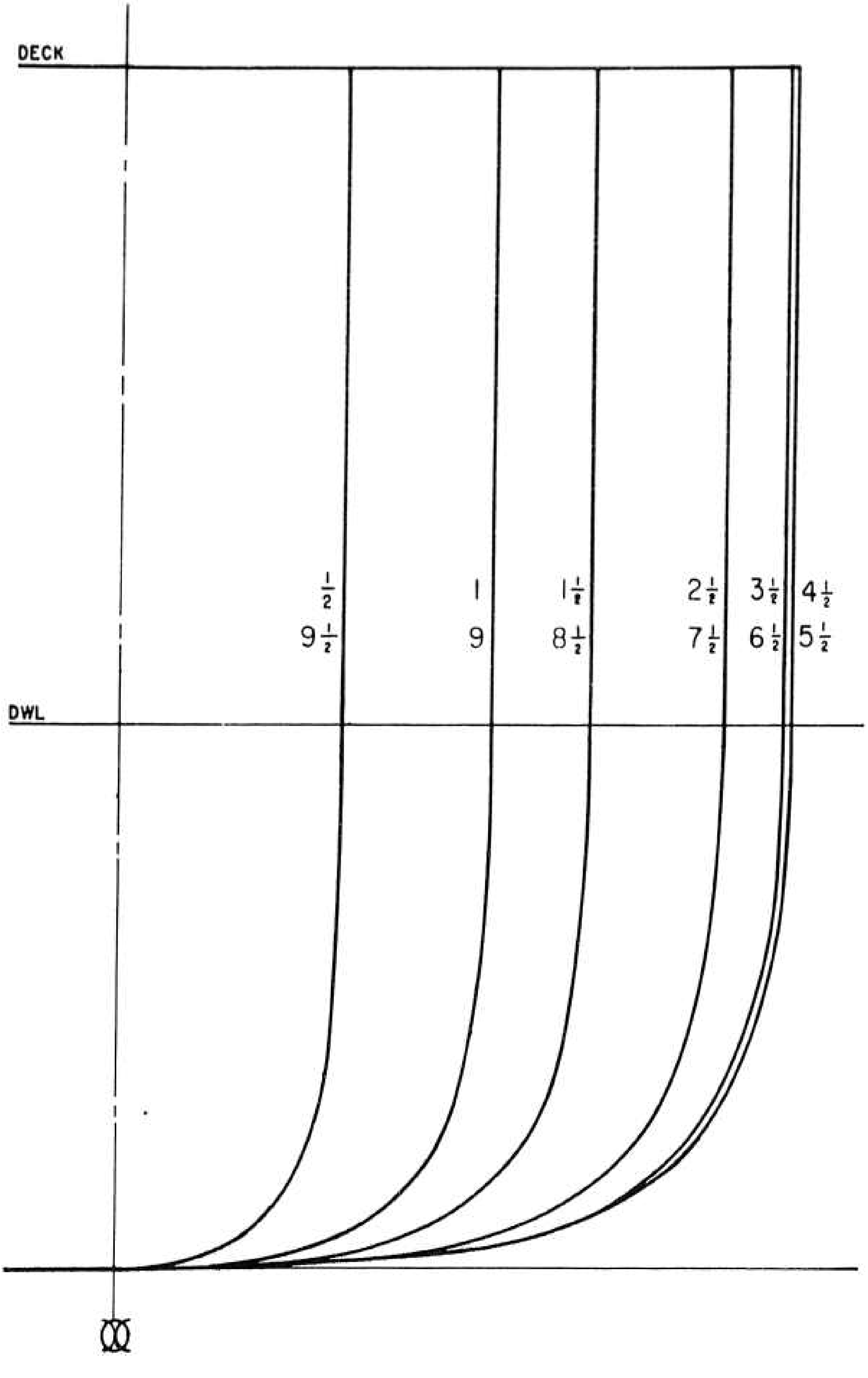
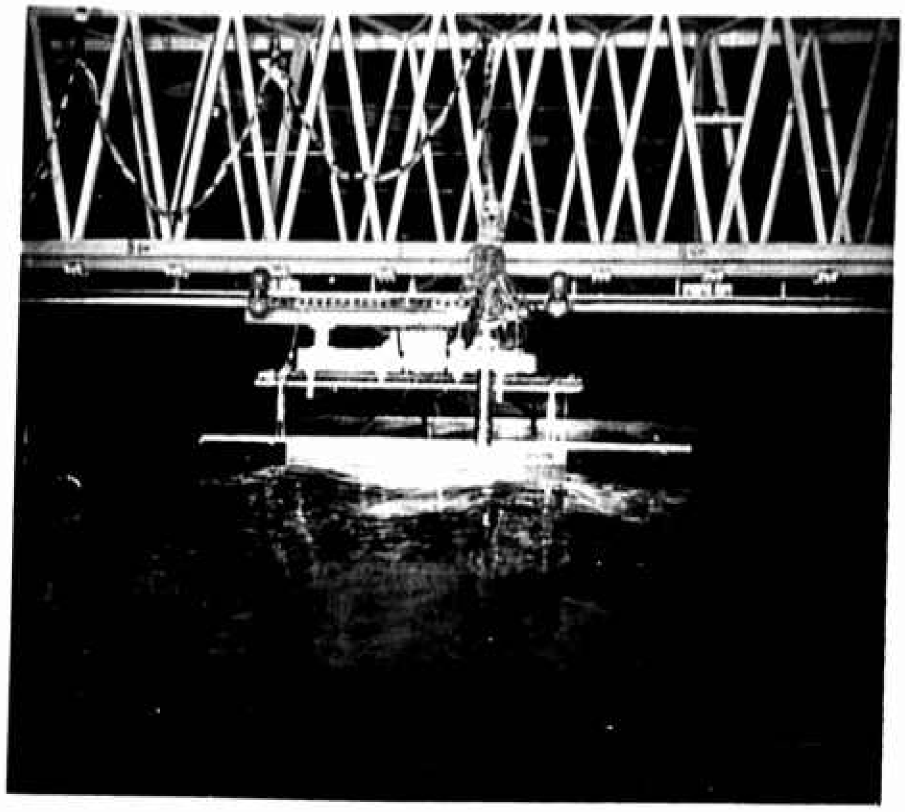
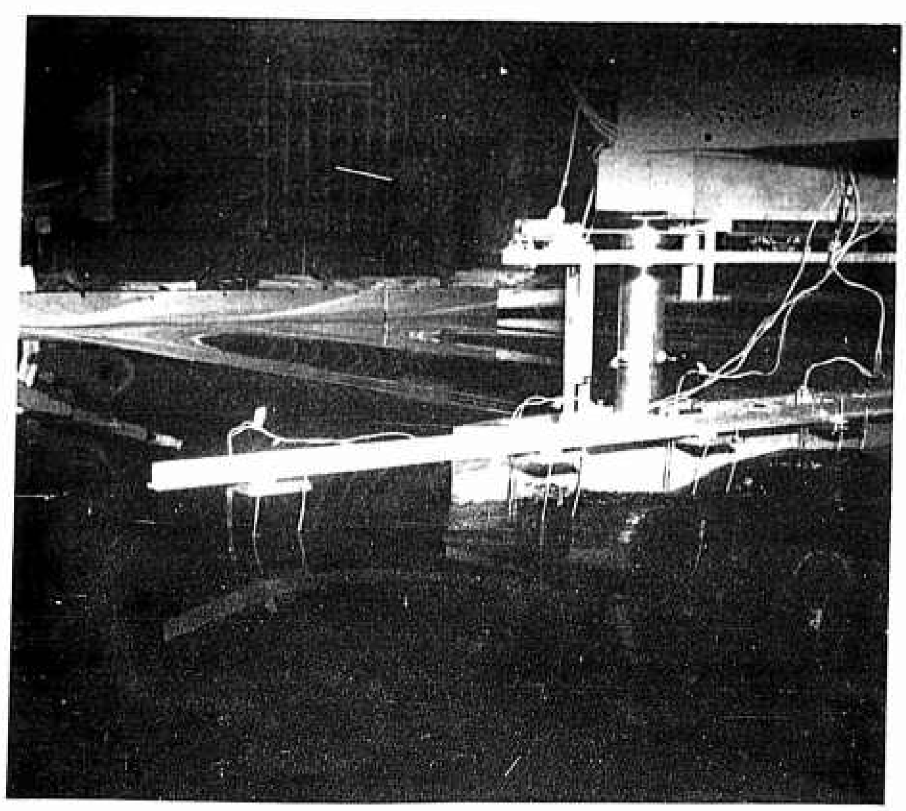


FIGURE 1. BODY PLAN OF D.L. MODEL 2698



a. Zero Speed λ/L = .75



b. Head Seas λ/L = .75 F = 0.3

FIG. 2 Test Set-up and Model in Waves

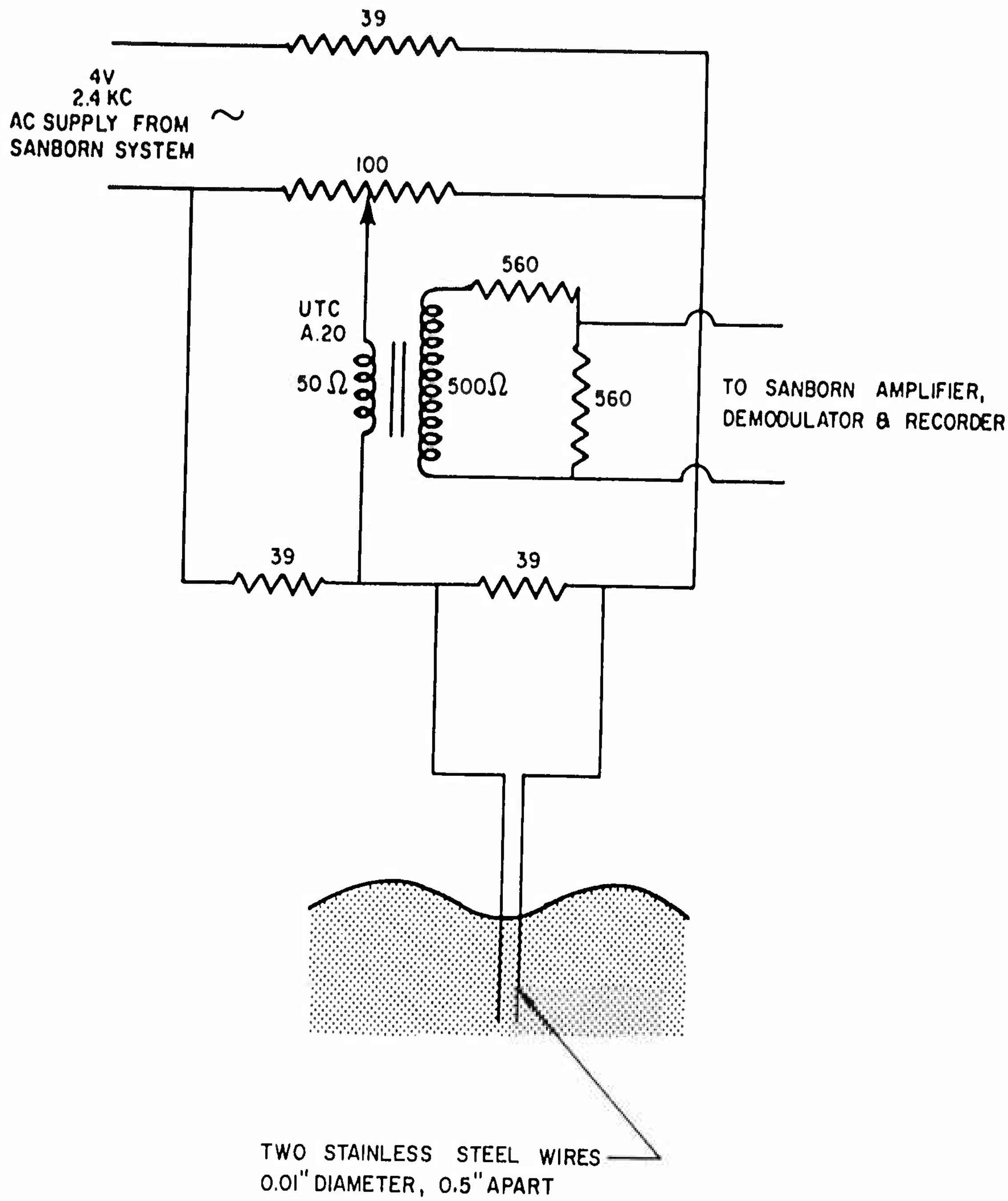


FIGURE 3. BRIDGE CIRCUIT FOR WAVE PROBES

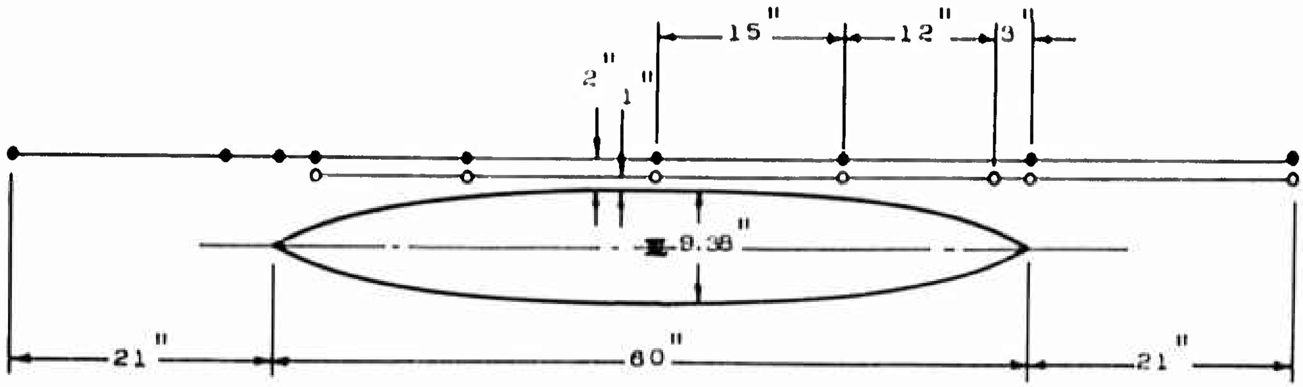


FIG. 4a. Positions of Wave Probes

In Figs. 5-10, the ordinates represent the ratios of the local wave amplitudes indicated by the various wave probes to the amplitude which the wave would have if it were not disturbed by the model.

The abscissae represent the fore-and-aft positions of the wave probes relative to the model, whose position is shown.

In each figure the wave travels from right to left. The direction of movement of the model is indicated by an arrow.

The transverse positions of the wave probes are indicated thus:

o – Line of wave probes 1" from model amidships

• – Line of wave probes 2" from model amidships

The positions of the wave probes are shown by similar symbols in Fig. 4a above.

Tails on the symbols are used where necessary to distinguish different test runs.

Curves are drawn as follows:

- - - - To indicate trend of experimental results

To show theoretical values given by Grim:

H_{23} Two- and three-dimensional effects combined

H_3 Three-dimensional effect only

Fig. 4b. Explanation of Figures 5-10

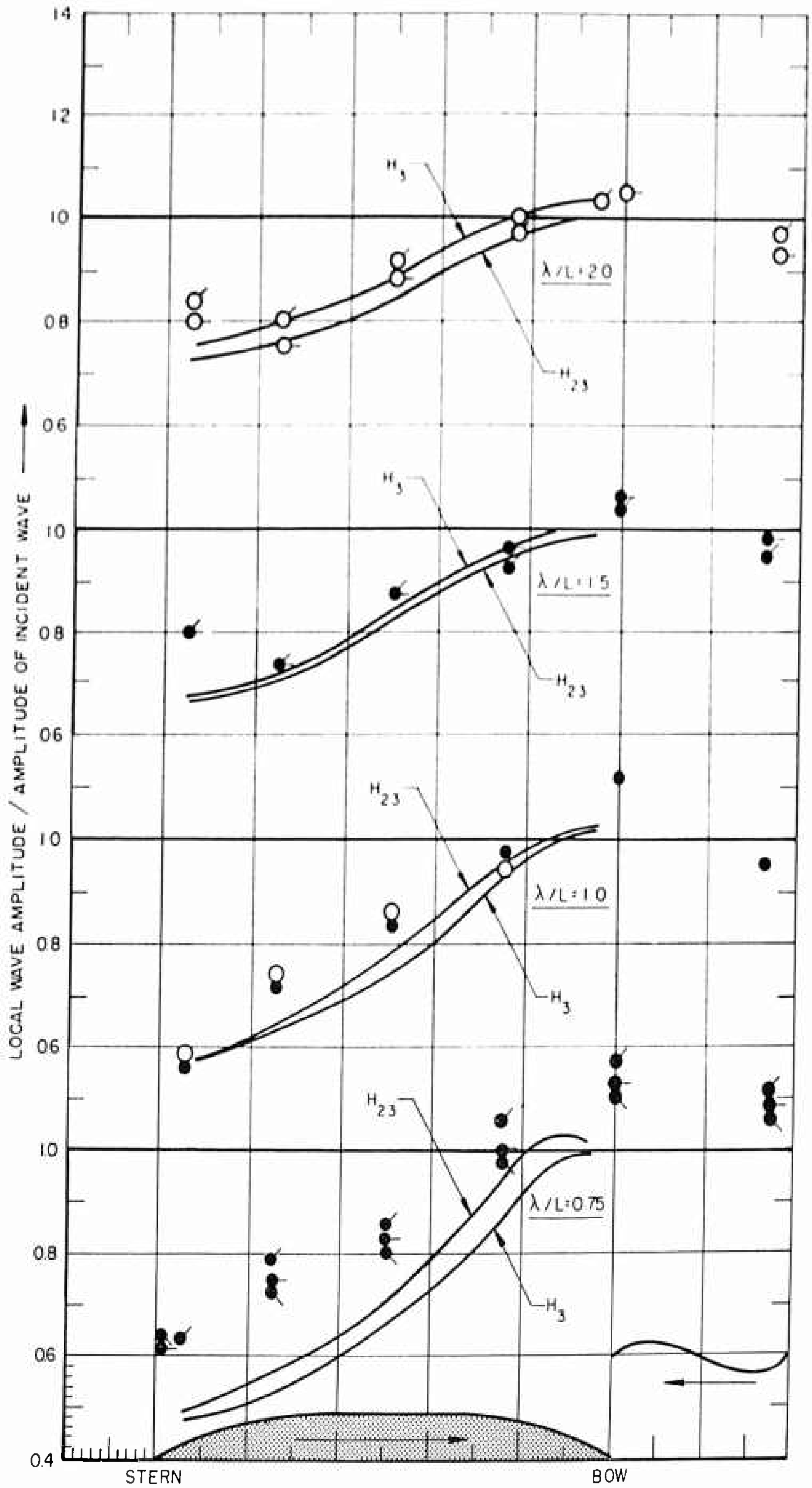


FIGURE 5. ZERO SPEED

FOR EXPLANATION SEE FIG. 4b.

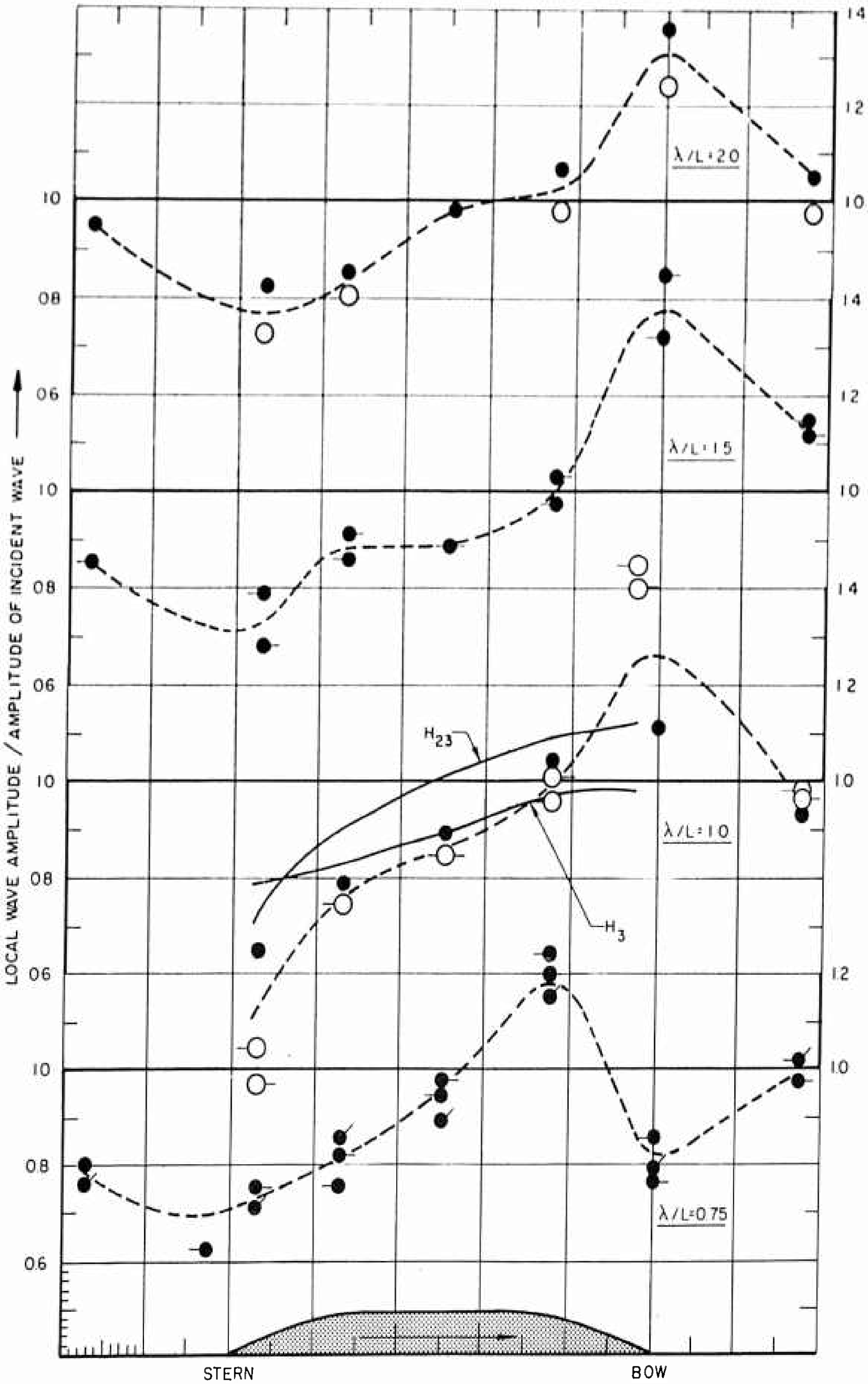


FIGURE 6. HEAD SEAS

F=0.1

FOR EXPLANATION SEE FIG. 4b.

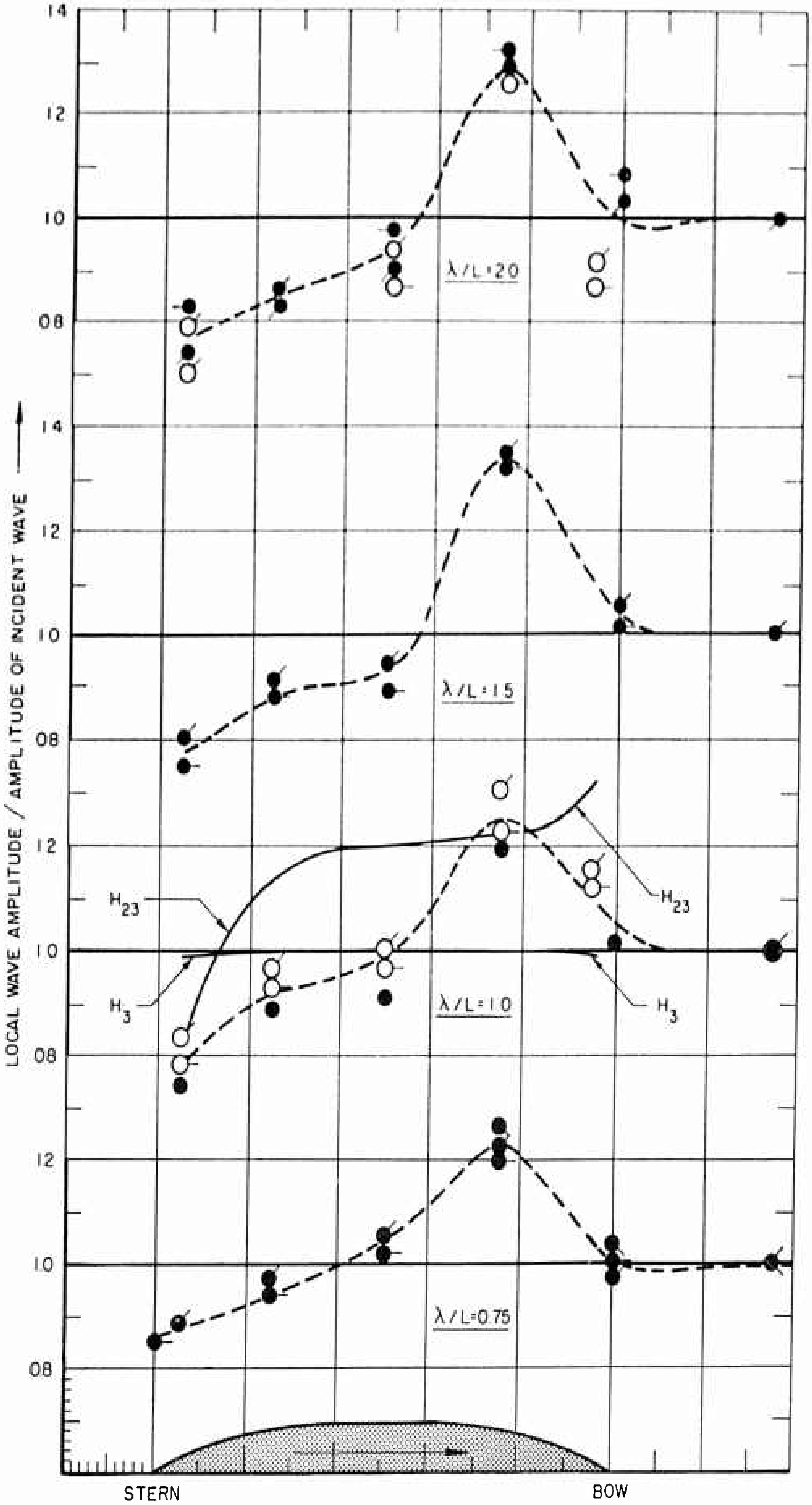


FIGURE 7. HEAD SEAS

F=0.3

FOR EXPLANATION SEE FIG. 4b.

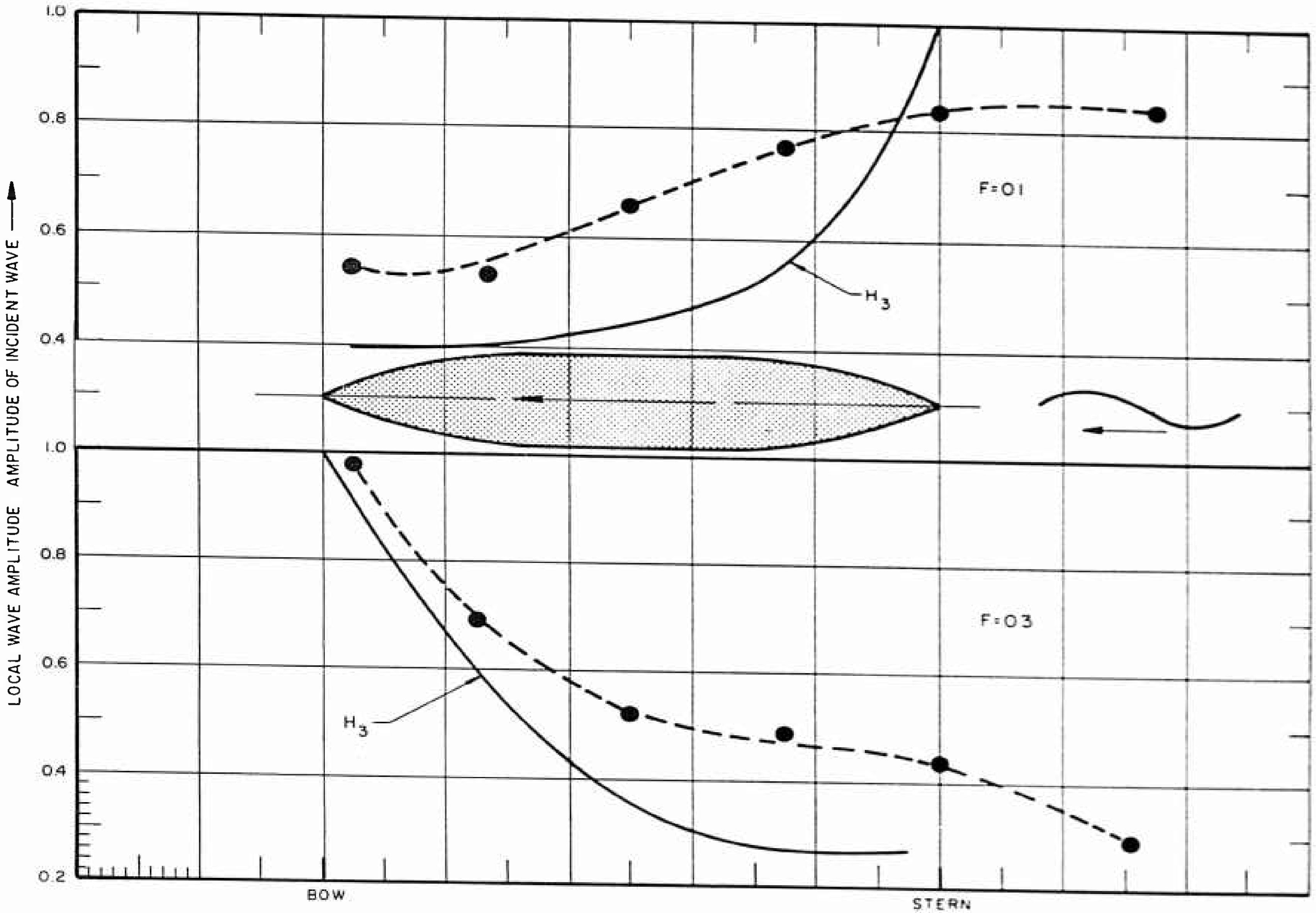


FIGURE 8. FOLLOWING SEAS $\lambda/L = 1.0$

FOR EXPLANATION SEE FIG 4b.

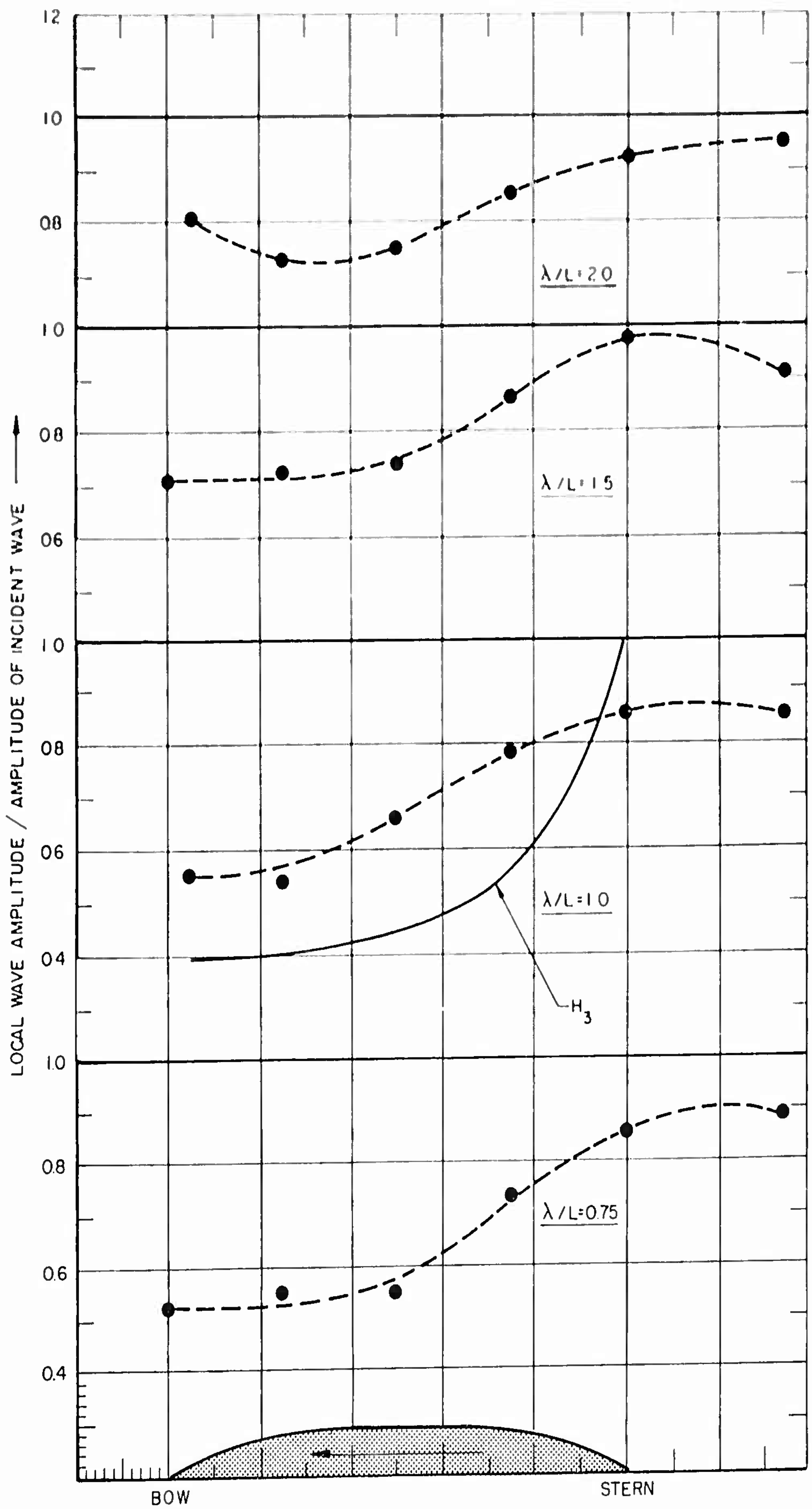


FIGURE 9. FOLLOWING SEAS

F=0.1

FOR EXPLANATION SEE FIG. 4b.

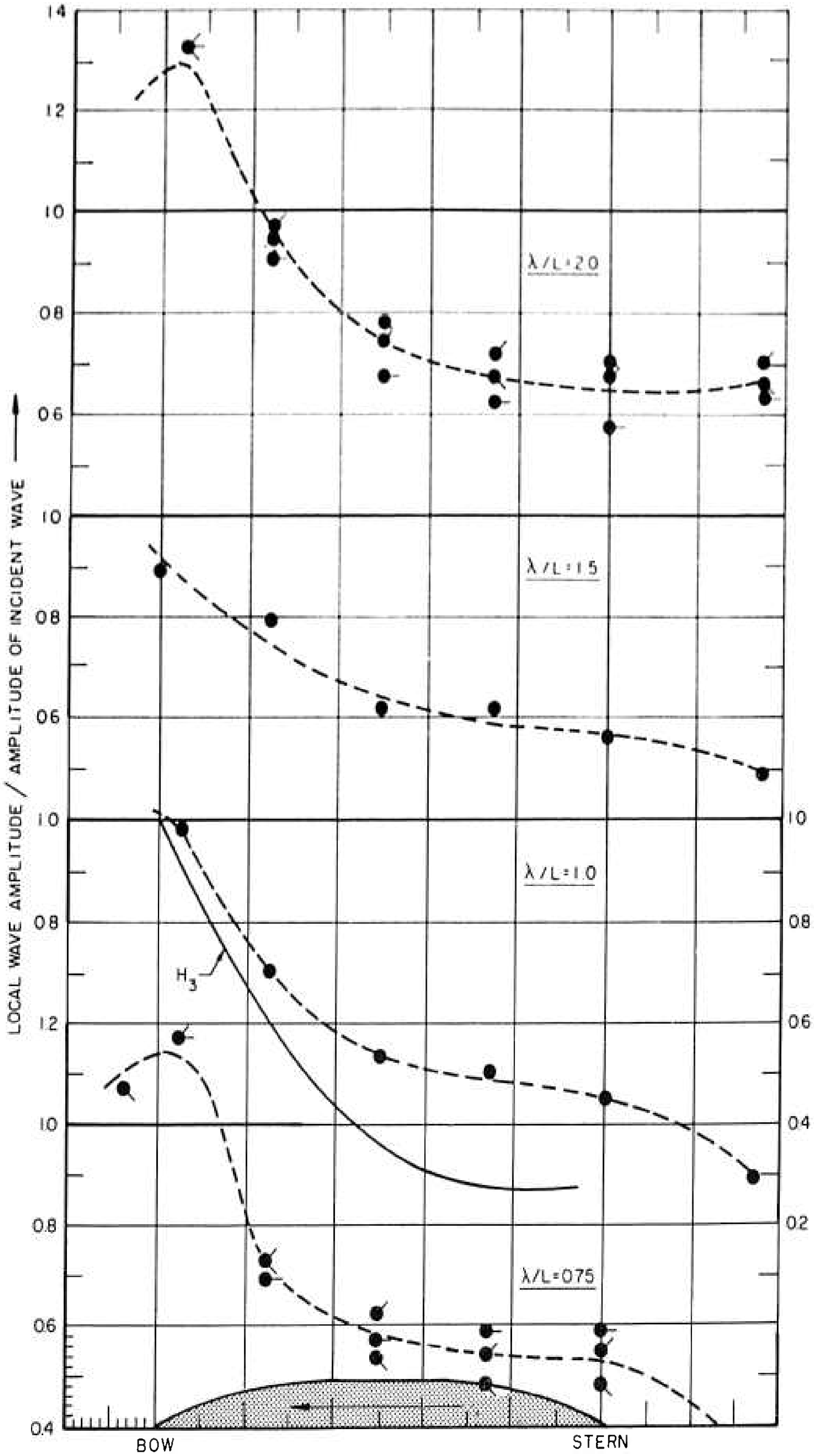


FIGURE 10. FOLLOWING SEAS

F=0.3

FOR EXPLANATION SEE FIG. 4b.

DISTRIBUTION LIST

No. of Copies	
20	Defense Documentation Center Cameron Station Alexandria, Virginia
1	Engineering Index, Inc. United Nations Plaza at 47th Street New York, N.Y.
11	Chief, Bureau of Ships Dept. of the Navy (Code 341B) (1) Washington 25, D.C. (Code 421) (1) Att: Technical Info. (Code 335) (3) Ship Silencing (Code 345) (1) Prelim. Design (Code 420) (2) Hull Design (Code 440) (1) Scientific and Research (Code 442) (1) Laboratory Mgt. (Code 320) (1)
1	Bethlehem Steel Company Shipbuilding Division Quincy 69, Mass. Attn: Mr. R.V. Danielson
1	Chief Bureau of Naval Weapons Department of the Navy Washington 25, D.C.
1	Applied Mechanics Reviews Southwest Research Institute 8500 Culebra Road San Antonio 6, Texas Attn: Editor
75	Commanding Officer and Director David Taylor Model Basin Washington 7, D.C. Attn: Code 513
5	Chief of Naval Research Dept. of the Navy Washington 25, D.C. Attn: Code 438 Code 466
2	Gibbs and Cox, Inc. 21 West Street New York 6, N.Y. Attn: Mr. W.F. Gibbs Mr. W. Bachman
1	Colorado State University Civil Engineering Section Fort Collins, Colorado Attn: Mr. E.F. Schulz
3	Massachusetts Inst. of Tech. Dept. of Naval Architecture and Marine Engineering Cambridge 39, Massachusetts Attn: Prof. M.A. Abkowitz Prof. G.C. Manning Prof. P. Mandel
1	Newport News Shipbuilding and Dry Dock Company Engineering Technical Dept. Newport News, Virginia Attn: Mr. John Kane
1	Oceanics, Inc. Technical Industrial Park Plainview, Long Island, N.Y. Attn: Mr. Wilbur Marks
1	Commanding Officer Office of Naval Research 1000 Geary Street San Francisco 9, Calif.
1	Commanding Officer Office of Naval Research 207 West 24th Street New York 11, N.Y.
1	Commanding Officer Office of Naval Research Navy 100, F.P.O. New York, New York
1	Commanding Officer Office of Naval Research 495 Sumner Street Boston 10, Massachusetts
1	Commanding Officer Office of Naval Research Branch Office 230 N. Michigan Avenue Chicago 1, Illinois
1	Commanding Officer Office of Naval Research 1030 East Green Street Pasadena 1, California
1	Office of Ship Construction Maritime Administration Washington 25, D.C. Attn: Mr. V.L. Russo, Deputy Chief

DISTRIBUTION LIST

No. of
Copies

1 University of California
College of Engineering
Berkeley 4, California
Attn: Mr. O.J. Sibul

1 University of Michigan
Dept. of Naval Architecture
and Marine Engineering
Ann Arbor, Michigan
Attn: Prof. R.B. Couch, Chairman

1 University of Notre Dame
Dept. of Engineering Mechanics
Notre Dame, Indiana
Attn: Dr. A.G. Strandhagen, Head

2 Commander
U.S. Naval Ordnance Laboratory
White Oak
Silver Spring, Maryland
Attn: Library

3 U.S. Naval Ordnance Test Station
Pasadena Annex
3202 E. Foothill Blvd.
Pasadena, California
Attn: Commander
Technical Library
Head, Thrust Producer Sec.

1 Hydronautics, Inc.
Pindell School Road
Laurel, Howard County, Md.
Attn: Philip Eisenberg

2 Institute of Engineering Research
University of California
Berkeley 4, California
Attn: Prof. H.A. Schade, Dir.
Dr. J.V.Wehausen,
Dept. of Engineering

1 IIT Research Institute
Technology Center
10 West 35th Street
Chicago 16, Illinois
Attn: Dr. I. Michelson

1 Dr. Louis Landweber
Iowa Institute of Hydraulic Res.
State University
Iowa City, Iowa

1 Maritime Administration
Engineering Specification Branch
Main Propulsion Section
Washington 25, D.C.
Attn: Mr. Ceasar Tangerini, Head

1 Director
U.S. Naval Research Laboratory
(Code 2000)
Washington 25, D.C.

1 Vidya Division
Itek Corporation
1450 Page Mill Road
Palo Alto, California
Attn: Dr. J. Nielsen

3 Webb Institute of Naval Architecture
Glen Cove, New York
Attn: Administrator
Post Graduate School
for Officers
Prof. E.V. Lewis

1 Director
Hydrodynamics Laboratory
California Inst. of Technology
Pasadena 4, California

1 Dr. Jack Kotik
Technical Research Group
Route 110
Melville, Long Island, New York

2 Ordnance Research Laboratory
Pennsylvania State University
P.O. Box 30
University Park, Pennsylvania
Attn: Dr. G. Wislicenus, Dir.
Mr. McCormac

1 Prof. B.V. Korvin-Kroukovsky
P.O. Box 247
East Randolph, Vermont

1 Reed Research, Inc.
1048 Potomac Street, N.W.
Washington 7, D.C.
Attn: Mr. S. Reed

1 Society of Naval Architects and
Marine Engineers
74 Trinity Place
New York, N.Y.

1 St. Anthony Falls Laboratory
University of Minnesota
Minneapolis, Minnesota
Attn: Dr. L.G. Straub, Director

1 Robert Taggart, Incorporated
400 Arlington Boulevard
Falls Church, Virginia

Mr. George Rosen
Head of Aerodynamics and Hydrodynamics
Hamilton Standard Div. of United
Aircraft Corporation
Windsor Locks, Connecticut

Davidson Laboratory Report No. 966

UNCLASSIFIED

BuShip FHR
S-R009-01-01
DTMB Cont.
Nonr 263(54)

EXPERIMENTAL MEASUREMENTS OF THE DEFORMATION OF REGULAR HEAD AND FOLLOWING SEAS BY A MODEL SHIP

by Paul G. Spens, June 1963

This report describes measurements of the changes in amplitude of regular head and following waves as they passed along the length of a ship model for model speeds zero, Froude number 0.1, and Froude number 0.3.

In head seas the height of the incident wave diminished by some 20% to 40% as it passed along the length of the fully restrained model from bow to stern. In following seas the wave diminished by some 50% from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas, there are local variations of wave height near the bow which are not predicted by the theory.

Davidson Laboratory Report No. 966

UNCLASSIFIED

BuShip FHR
S-R009-01-01
DTMB Cont.
Nonr 263(54)

EXPERIMENTAL MEASUREMENTS OF THE DEFORMATION OF REGULAR HEAD AND FOLLOWING SEAS BY A MODEL SHIP

by Paul G. Spens, June 1963

This report describes measurements of the changes in amplitude of regular head and following waves as they passed along the length of a ship model for model speeds zero, Froude number 0.1, and Froude number 0.3.

In head seas the height of the incident wave diminished by some 20% to 40% as it passed along the length of the fully restrained model from bow to stern. In following seas the wave diminished by some 50% from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas, there are local variations of wave height near the bow which are not predicted by the theory.

Davidson Laboratory Report No. 966

UNCLASSIFIED

BuShip FHR
S-R009-01-01
DTMB Cont.
Nonr 263(54)

EXPERIEMTAL MEASUREMENTS OF THE DEFORMATION OF REGULAR HEAD AND FOLLOWING SEAS BY A MODEL SHIP

by Paul G. Spens, June 1963

This report describes measurements of the changes in amplitude of regular head and following waves as they passed along the length of a ship model for model speeds zero, Froude number 0.1, and Froude number 0.3.

In head seas the height of the incident wave diminished by some 20% to 40% as it passed along the length of the fully restrained model from bow to stern. In following seas the wave diminished by some 50% from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas, there are local variations of wave height near the bow which are not predicted by the theory.

Davidson Laboratory Report No. 966

UNCLASSIFIED

BuShip FHR
S-R009-01-01
DTMB Cont.
Nonr 263(54)

EXPERIMENTAL MEASUREMENTS OF THE DEFORMATION OF REGULAR HEAD AND FOLLOWING SEAS BY A MODEL SHIP

by Paul G. Spens, June 1963

This report describes measurements of the changes in amplitude of regular head and following waves as they passed along the length of a ship model for model speeds zero, Froude number 0.1, and Froude number 0.3.

In head seas the height of the incident wave diminished by some 20% to 40% as it passed along the length of the fully restrained model from bow to stern. In following seas the wave diminished by some 50% from stern to bow when the ship speed was less than the wave group velocity, and from bow to stern when the ship speed was greater than the wave group velocity.

These experimental results are generally in fair agreement with Grim's theoretical predictions. However, at forward speeds in head seas, there are local variations of wave height near the bow which are not predicted by the theory.